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A PERSPECTIVE ON ATMOSPHERIC NUCLEAR TESTS IN NEVADA

FACT BOOK

Prepared for the

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
LAS VEGAS, NEVADA

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CONTENTS

AGENCY ACRONYMS

AEC — United States Atomic Energy Commission; sometimes shown as U.S. AEC or USAEC (see DOE).

DoD — Department of Defense.

DOE — Department of Energy. The AEC was established on August 1, 1946, and abolished on January 19, 1975, when many AEC functions were transferred to the newly created Energy Research and Development Administration (ERDA). ERDA was abolished on October 1, 1977, and many of the agency's functions were transferred to the new DOE.

GAO — Government Accounting Office. An office, under the Office of the Comptroller General of the United States, which conducts investigations at the request of the U.S. Congress.

MLC — Military Liaison Committee. An organization established by the Atomic Energy Act of 1946, as amended, to maintain liaison between the Atomic Energy Commission and the Department of Defense.

NTS — Nevada Test Site. A 1,350-square-mile area in Nye County, Nevada, located about 65 miles northwest of Las Vegas.

ORERP — Off-Site Radiation Exposure Review Project. A large project, begun in 1979 by the Nevada Operations Office of the DOE, to reassess radiation doses received by residents downwind of the nuclear testing site in Nevada and to make available to the public at one location an archive of information concerning nuclear testing and fallout.

PREFACE - SECOND REVISION

The last nuclear test by the United States was conducted at the Nevada Test Site on September 23, 1992. The United States has since then observed a moratorium on nuclear testing and has vowed to forego new tests so long as other nuclear powers do the same. (Although China has conducted three underground nuclear tests since September 1992, the United States has continued to observe the self-imposed moratorium.)

In December 1993, Department of Energy Secretary Hazel O'Leary disclosed previously classified information regarding 204 nuclear tests, conducted at the Nevada Test Site between 1963 and 1990, which had not been publicly announced. ALL nuclear tests conducted by the United States have now been announced. The disclosure reflects a new "openness" policy for Department activities both past and present. None of the 204 tests released radiation detectable beyond the borders of the Test Range Complex although 37 of these tests did release small amounts of radioactivity detectable on the NTS. All but two of the tests produced yields of less than 20 kilotons. Table 3 of this fact book has been revised to include the newly released information.

Reference 5, "Radiological Effluents Released From Announced U.S. Continental Tests, 1961 Through 1988," has been revised to incorporate information about the previously unannounced tests and is in final review as this fact book goes to press. When published, it will have a slightly revised title but will retain document number DOE/NV-317. Some minor differences in "curies released" are possible between the revised DOE/NV-317 and information presented in Table B.4.b. of this fact book.

H. N. Friesen
June 22, 1995

PREFACE - FIRST REVISION

Much has happened since 1985 to justify updating this fact book. History has not changed, but some new details can now be reported. For example, radioactivity from two unannounced tests conducted during the 1960s was detected off the Test Range Complex. To comply with the DOE's present policy of announcing ALL tests producing radioactivity detected off site, these two previously unannounced tests are now included in the data presented in Table 3. Recent thorough reexamination of monitoring data collected during the 1960s led to changes in the designations of several other tests. These changes involve detection of minor amounts of radioactivity between 1962 and 1970. In some cases, detected radiation was determined to be from a nuclear test conducted by China, thus a U.S. test would be counted in a different category than it was previously. A comparison of the old and new Table 3 will therefore show several differences.

As a result of many years of effort by others, certain data are now available to be reported in an easily understood format. For example, old Table B.4 expressed radioactive releases in terms of "off site," "minor off site," and "detected by aircraft." New Table B.4.b presents releases in terms of an estimate of Curies released; this estimate is based on measurements of radioactivity at and following release time. These data are taken from a recently published DOE document.

Lawsuits against the U.S. government have progressed through the courts, and several final decisions can now be presented. Several new developments in the legislative arena merit some discussion, although the last word on this subject has not been uttered.

Lastly, the University of Utah recently completed studies funded by the National Cancer Institute. These studies examined the possibility of a relationship between fallout from nuclear tests and certain alleged health effects in the downwind population; results of these studies are briefly presented.

H. N. Friesen
April 1992

I. INTRODUCTION

Development and testing of nuclear devices[1] and study of the effects of nuclear weapons have been ongoing tasks of the U.S. government since 1941. The first nuclear detonation was accomplished at Alamogordo, New Mexico, on July 16, 1945. After World War II, Bikini and Enewetak Atolls (Enewetak was formerly spelled Eniwetok), located in a remote area of the Pacific Ocean, were selected as sites for the first two series of postwar nuclear tests. From 1951 through 1958, nuclear tests were conducted in the atmosphere both in the Pacific and at a continental site in southern Nevada. Radioactive fallout from some of the Nevada tests was carried by the wind from the Test Range Complex to communities nearby. Residents were told that fallout radiation levels were being monitored, and they were assured no adverse health effects would result.

A series of events beginning in 1977—26 years after the first test in Nevada—rekindled interest in the subject of radioactive fallout from the atmospheric nuclear tests. During 1977, national publicity was given to the claim that an excessive number of cases of leukemia occurred among military observers of the SMOKY nuclear test of August 31, 1957. Following this publicity, numerous claims were filed against the U.S. government through the Department of Energy by residents of Nevada, Utah, and Arizona. Claimants maintain that Atomic Energy Commission officials were negligent in conducting the nuclear tests during the 1950s. (AEC nuclear testing functions are now administered by the AEC's successor agency, DOE.) Residents claim the government should have given them more information so they could protect themselves from the radioactive fallout and that fallout radiation has caused death, ill health, and suffering. The position of the U.S. government is that doses resulting from exposures to radioactive fallout were not sufficient to cause the injuries claimed.

This fact book provides historical background and perspective on the nuclear testing program at the Nevada Test Site (NTS). Nuclear tests contributing to the off-site deposition of radioactive fallout are identified, and the concept of cumulative estimated exposure is explained. The difficulty of associating health effects with radiation is presented also. The status of litigation against the government and legislation as of September 1994 are summarized.

Another fact book, "Off-Site Radiation Exposure Review Project," available from the locations shown inside the front cover of this fact book, provides brief explanations of why the exposure review was started, how it was organized, and the method used for peer review.

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[1] Underlined words are defined in Appendix A.

The two main project objectives are presented in some detail. Project results available as of September 1994 are also summarized.

II. HISTORICAL PERSPECTIVE[2]

The first detonation of a nuclear bomb, a fission device code-named TRINITY, was accomplished on July 16, 1945, as a field test by the United States near Alamogordo, New Mexico. Three weeks later the second and third nuclear bombs were detonated over Hiroshima and Nagasaki, Japan, respectively. The detonation in combat of these powerful weapons brought a quick end to the war with Japan. Though effective, the devices were crude and unwieldy by later standards. Refinements in design, construction, and method of delivery would be necessary to convert the first primitive devices into practical elements of a nuclear stockpile. Design changes would have to be tested in the field to ensure performance and reliability. Until the early 1950s, most aspects of nuclear weapons design and testing were the responsibility of the Los Alamos Scientific Laboratory (LASL, now the Los Alamos National Laboratory, LANL) located at Los Alamos, New Mexico.

After the war with Japan, intense debate ensued among politicians, military planners, and atomic scientists over control of atomic energy. President Truman settled the issue on August 1, 1946, when he signed the Atomic Energy Act of 1946 which established the Atomic Energy Commission. The Commission was composed of five civilians appointed by the President. The Act provided for both peaceful and military uses of atomic energy and, while implementing civilian control over all atomic energy facilities and programs, stressed the paramount objective of assuring the common defense and security. The Act also established three major advisory committees to assist and oversee the AEC: the Congressional Joint Committee on Atomic Energy (JCAE), a five-member Military Liaison Committee (MLC) appointed by the Secretaries of War and Navy (by the Secretary of the Department of Defense after July 1947), and a nine-member General Advisory Committee of scientists appointed by the President. The AEC bore responsibility for development, production, and control of atomic resources in a coordinated effort with these three oversight and advisory committees.

A. NUCLEAR TESTING BEFORE NOVEMBER 1958

Scientists knew before the TRINITY test that a nuclear detonation in the atmosphere would produce radioactive contaminants which would fall to the ground downwind of the explosion. To minimize radiation exposure to populated areas, sites in the Marshall Islands of Micronesia were selected for the first two series of postwar nuclear tests. These test series were conducted at Bikini Atoll in 1946 and Enewetak Atoll in 1948. Use of these

[2] Text through Subsection A.2. is summarized primarily from References [1] and [2].

remote sites, called collectively the Pacific Proving Ground, was found to be very expensive due to problems of operating and maintaining supply lines for construction materials and equipment and for support of personnel. Security was also considered a major potential problem. The outbreak of the Korean War raised concerns about the ability of the United States to maintain security at the Pacific Proving Ground and to continue providing military vessels and personnel in support of nuclear tests.

1. Continental Test Site

As early as 1948, the Joint Chiefs of Staff of the Department of Defense (DoD) and the MLC supported establishment of a test site within the continental United States. Several candidate sites were included in a feasibility study, and a lengthy report was submitted to the AEC recommending selection of such a site. The AEC did not approve the recommendation in 1948, rejected it again in 1949, but suggested reconsideration in the event of a national emergency.

The Soviet Union detonated its first nuclear device in August 1949. This early development of nuclear science by the Soviet Union was not expected by the U.S. government and created much concern among high-level officials. The effect of the Soviet success was to begin an arms race between the Soviet Union and the United States for superiority in nuclear weapons. Scientists in the United States suggested that a device fueled with isotopes of hydrogen (a fusion device) could be developed as the ultimate weapon of nuclear superiority. Research in this area was stepped up at the same time government officials were being convinced of the feasibility of such a weapon. President Truman announced to the public in January 1950 his decision to authorize development of the hydrogen bomb as the nation's first line of defense. To produce a usable fusion weapon, the fission device had to be designed to create the high pressure and temperature conditions needed to start the fusion reaction before the device blew apart. The key to progress was testing of nuclear device designs. Two kinds of tests were required by the designers. Testing of small-scale devices was required to improve and refine the fission design and to provide needed information on fusion principles. Large-scale testing of experimental, developmental, and prototype devices was necessary prior to producing these weapons for the stockpile.

In 1950, the Chairman of the AEC suggested to the MLC Chairman that hostilities in Korea might constitute the national emergency envisioned in 1949 and requested a joint study of potential continental test sites by AEC and DoD. Also in 1950, President Truman directed the National Security Council to study the alternatives and recommend a continental

site for early use. The AEC intended that a continental site would be used for diagnostic testing of low-yield devices, whereas devices with higher yields would be tested only at Pacific sites.

The extensive study to establish a continental testing site by the AEC and DoD included the views of many experts from the AEC staff, other agencies of government, and the nongovernment community. Of primary concern was radiological safety, which required favorable and predictable wind conditions and only a sparse population in the prevailing downwind direction. The study recommended selection of part of the Las Vegas Bombing and Gunnery Range in southern Nevada as the location for more testing of relatively small nuclear devices and weapons. This largely desert area, 65 miles northwest of Las Vegas, was considered to be suitably remote. The recommendation was approved by the AEC and the National Security Council and was sent to President Truman who announced his approval on December 18, 1950. A portion of the Las Vegas Bombing and Gunnery Range (now known as the Nellis Air Force Range) became the AEC's continental nuclear testing site.

In response to world conditions, the AEC developed a second nuclear weapon laboratory in 1952, the Lawrence Radiation Laboratory (LRL, now the Lawrence Livermore National Laboratory, LLNL) at Livermore, California, and doubled the efforts of the United States to produce more efficient and smaller fission devices and to develop a fusion weapon ahead of the Soviet Union. The ability of the United States to quickly test fission devices used to trigger the fusion weapon was a significant factor in the United States maintaining its nuclear arms lead over the Soviet Union. The NTS provided the capability to perform land-based diagnostic tests on the fission devices at a site relatively close to the nuclear weapon laboratories.

The Pacific Proving Ground continued to be used for a variety of complex tests and large-yield devices during 1951, 1952, 1954, 1956, and 1958. Nuclear tests were conducted aboveground at the NTS during the period 1951 to 1958, with no tests during 1954 and one safety experiment in January 1956 which is usually counted as part of the 1955 test series.

2. Atmospheric Testing

Nuclear testing at the NTS has been conducted in two distinct eras. The first era extended from January 1951 through October 1958. During this period, most tests were conducted aboveground (atmospheric testing). The United States stopped all testing on October 31, 1958, and the Soviet Union did the same on November 3, 1958. Nuclear testing was stopped as the result of separate, self-imposed moratoriums. The Soviet Union broke its

moratorium on September 1, 1961, and the United States responded with renewed testing on September 15, 1961.

The second era extended from 1961 through 1992. During this period, almost all nuclear tests by the United States were conducted underground. A few surface and near-surface cratering tests were conducted between 1961 and 1968 along with the underground tests. (The United States also conducted 35 tests in the atmosphere as part of the Pacific Operations Program during 1962.) The United States, Great Britain, and the Soviet Union signed the Limited Test Ban Treaty on August 5, 1963, which effectively banned these countries from testing nuclear weapons in the atmosphere, in outer space, and underwater.

This fact book emphasizes the era of atmospheric testing at the NTS because nearby off-site populations were—and still are—concerned about health effects from radioactive fallout.

The United States conducted 120 nuclear tests in the Test Range Complex from the start of testing in January 1951 through October 1958. Only one of these tests, PROJECT 57-1, was conducted off of the NTS proper. PROJECT 57-1 was a safety experiment with no nuclear yield. Table 1 presents summary information for these 120 tests by year and by yield. (Yield is expressed in kilotons [kt]. Information presented in Tables 1 and 2 is abstracted from Appendix Tables B.1, B.2, and B.3.)

TABLE 1. NUCLEAR TESTS AT THE NTS, 1951-1958

Year	Number of Tests	Yield, kt Total	Yield, kt Average	Yield, kt Range
1951	12	112	9	<0.1 - 31
1952	8	104	13	1 - 31
1953	11	252	23	0.2 - 61
1955	18	167	10	0 - 43
1957	32	344	11	0 - 74
1958	39	46	1	0 - 22
Totals	120	1025		
Average			9	
Range				0 - 74

Test numbers and yields shown in Table 1 are categorized in Table 2 by the location of the device (burst point) in relation to ground surface and by yield groups. Larger-yield tests in the surface and low altitude open-air categories were most likely to produce radioactive

fallout outside of the Test Range Complex; 39 such tests have been indicated by an asterisk (*) in the body of Table 2.

TABLE 2. NUMBER OF NUCLEAR TESTS AT THE NTS, 1951-1958, BY LOCATION OF BURST POINT AND BY YIELD GROUP

	Yield, kt				Test
Location	Below 1	1 thru 9	10 thru 19	20+	Totals
Open Air:					
Under 1000 ft.	6	5*	3*	1*	15
Above 1000 ft.	1	15	7	7	30
Open Air Total	7	20	10	8	45
Surface	25	8*	13*	9*	55
Underground	17	2	0	1	20
Totals	49	30	23	18	120

NOTE: Open-air and surface tests are usually combined into the "atmospheric" category. See discussion of terms in Appendix B. Some of the underground tests, conducted in drilled shafts open to the surface, were not designed to be contained; these tests have been called "Roman candles" because of the way they spewed dust and radioactive effluent into the atmosphere.

3. Characteristics of Fallout[3]

Detonation of a nuclear fission device produces an instantaneous transformation of atoms accompanied by a tremendous release of energy. The energy is released when heavy atoms are split into lighter atoms. The newly created lighter atoms are collectively referred to as fission products, most of which are radioactive. The total energy released is called the yield, which is directly related to the quantity of material that undergoes fission. The quantity of fission products produced is therefore closely related to the yield.

A nuclear detonation in the atmosphere creates a fireball of extremely high temperature which vaporizes everything in the immediate area. A fireball close to the ground will sweep a substantial quantity of soil up into the <u>mushroom cloud</u> and its <u>stem</u>. As the fireball rises and cools, some of the vaporized materials condense from the gaseous state to form solid particles. Radioactive fission products also condense and collect on the solid particles (soil and other materials) which have been drawn into the cloud. Larger particles fall to the earth's surface within about 24 hours (close-in or local fallout). Very small particles may be carried to high altitudes and then fall to earth over a period of several years

[3] Material in this section is summarized primarily from Reference [4].

(worldwide or global fallout). When the fireball is at an altitude high enough to avoid contact with the ground (as in most airdrops), soil particles are not drawn into the cloud so condensation particles are much smaller and lighter and, therefore, less apt to appear as fallout in a short time and distance.

Detonation of a nuclear device creates hundreds of different radioactive atoms (radionuclides). Most of these decay to stable elements within the first few seconds and minutes. About 160 nuclides may still be radioactive after one hour. Fallout occurring a few hours after detonation may contain about 80 different radionuclides. As these radioactive atoms continue to decay, the number of original radionuclides drops while new daughter products form. Over a period of time, most of the atoms become stable (nonradioactive) leaving a residue consisting of a few radionuclides of relatively low activity.

The term "half-life" is used to characterize the rate of decay of a radioactive substance. Radionuclides that decay slowly have a long half-life; those that decay more rapidly have a shorter half-life. For example, strontium-90 decays to half of a given starting value in 28 years, but iodine-131 diminishes by one-half in 8 days. If iodine-131 had a starting value of 100 units (of radioactivity), 8 days later it would have 50 units; after another 8 days it would have 25; another 8 days, 12.5; etc. After seven half-lives (56 days), the activity would be less than one percent of the starting value.

The half-lives of most radioactive species created by a nuclear detonation, and present in fallout, span a wide range of values from less than one second to over 30 years. Radionuclides with less than a 7-day half-life virtually disappear within eight to ten weeks by becoming stable. Only about 20 radionuclides in fallout have a half-life of more than 7 days, and these constitute the long-term residue. Because the level of radioactivity in fallout diminishes almost to the level of natural background in about one year and continues to decrease, very little radioactivity remains in fallout residue in communities that received fallout during the 1950s, but this residue is currently still detectable by sensitive instruments.

4. Weather Conditions at Test Time

Two of the more significant considerations in the selection of a continental nuclear test site were a sparsely populated area and predictability of local weather. (The number of residents in the expected downwind fallout sector to a distance of about 150 miles had to be small enough to be quickly evacuated in the case of an emergency. Wind speed and direction at different altitudes, and the probability of rain to a distance of 300 miles in the fallout sector, had to be predictable for at least 12 hours prior to a test.) The desert region of

southern Nevada was sparsely populated in the late 1940s and early 1950s, and favorable and predictable weather conditions were expected with an acceptable frequency in the area where the NTS is located.

The least desirable weather condition at test time would produce a very narrow fallout track with large quantities of radioactivity passing directly over or falling on a populated area. The most desired weather conditions would produce a broad, fan-shaped pattern in which the fallout would be widely dispersed over an unpopulated area at a low level of radioactivity. The desired result could be approximated when the wind speed and/or direction varied with altitude. This condition is known as a wind shear.

Meteorologists working at the NTS constructed a map of the anticipated fallout pattern before each nuclear test and continually updated the map as weather conditions changed and the time of detonation drew near. Many tests were delayed, some for many days, because weather conditions were not acceptable. Very few tests were conducted with small amounts of wind shear and then only if the meteorological predictions indicated that fallout should miss populated areas.

B. NUCLEAR TESTING AFTER SEPTEMBER 1961

1. Underground Testing

Nuclear tests were conducted aboveground in the 1950s because the methods available for obtaining vital measurements of device performance required long distances for line-of-sight observation, photography, and instrumented measurements. Due to concerns by the AEC and the public about the long-term health consequences of fallout, methods were developed in the mid-1950s to contain detonations underground while still obtaining required information. Three cratering tests conducted in 1968 were the last tests which were not designed to contain all radiation.

Table 3 presents the number of tests by year since 1961 for all tests, for tests from which no release was detected, and for various categories of releases of radioactivity. The term <u>accidental release</u> refers to releases from shaft and tunnel tests from which no release was expected and includes the range from prompt <u>venting</u> to <u>late-time seepage</u>. The term <u>other releases</u> refers to <u>operational releases</u> (<u>drillback</u>, <u>gas sampling</u>, and <u>cementback</u> operations) and <u>controlled releases</u> (<u>tunnel purges</u>). Accidental and other releases are further divided to indicate that radioactivity was detected <u>on site</u> only, or was detected off site.

TABLE 3. NUCLEAR TESTS AT THE TEST RANGE COMPLEX ASSOCIATED WITH THE RELEASE OF RADIOACTIVITY DETECTED IN THE ATMOSPHERE, 1961-1992[1]

			Accidental Releases[2]		Other Releases[3]		
Year (1)	Total Tests (2)	No Release Detected (3)	Detected On Site Only (4)	Detected Off Site (5)	Detected On Site Only (6)	Detected Off Site (7)	Secondary Release[4] (8)
1961	9	0	7	2	0	0	2
1962	62	6	19	5	27	5	17
1963	46	11	9	1	21	4	8
1964	46	10	15	4	15	2	9
1965	38	9	11	3	14	1	5
1966	47	16	10	5	16	0	5
1967	41	23	5	3	9	1	3
1968	55	30	12	1	9	3	1
1969	44	26	11	2	5	0	1
1970	39	20	9	2	7	1	3
Subtotal	427	151	108	28	123	17	54
1971	23	19	1	1	2	0	1
1972	27	26	0	0	1	0	0
1973	23	18	0	0	5	0	0
1974	23	19	0	0	4	0	0
1975	22	21	0	0	1	0	0
1976	21	18	0	0	3	0	0
1977	20	15	0	0	5	0	0
1978	21	18	0	0	3	0	0
1979	16	14	0	0	2	0	0
1980	17	11	0	1	5	0	0
1981	17	12	0	0	5	0	0
1982	19	12	0	0	7	0	0
1983	19	11	0	0	8	0	0
1984	20	14	1	0	5	0	2
1985	18	11	0	0	6	1	0
1986	15	5	0	0	8	2	0
1987	15	9	0	0	6	0	0
1988	15	11	0	0	4	0	0
1989	12	8	0	0	4	0	0
1990	9	5	0	0	4	0	0
1991	8	8	0	0	0	0	0
1992	6	6	0	0	0	0	0
Subtotal	386	291	2	2	88	3	3
Totals	813	442	110	30	211	20	57

1 Abstracted from References [1] and [5].

2 Accidental release = test environment failed to contain all radioactivity immediately following device detonation.

3 Other release = radioactivity was detected hours or days following device detonation. (See glossary for definitions and text for discussion.)

4 Secondary release = both accidental and other releases detected from the same test. In each case, subject tests are counted in the category appropriate for the primary release. (See text for further discussion.)

When both accidental and other releases were detected from the same test, the larger of the releases is called, in this report, the primary release and the smaller is called the secondary release. For example, a release may have been detected immediately after a test and another release from the posttest cavity during drillback or cementback operations. The larger of the two releases is called the primary release, and the test is counted in only the primary release category. (In Table 3, Columns 4, 5, 6, and 7 are the primary release categories; these plus Column 3 sum to the number in Column 2. Column 8 is not included in the sum because this would be double counting.)

After tests PLATTE (4/14/62), DES MOINES (6/13/62), DRILL (12/5/64), FENTON (4/23/66), and DOOR MIST (8/31/67), both primary and secondary releases were detected off site. After tests PAMPAS (3/1/62), YUBA (6/5/63), EAGLE (12/12/63), ALVA (8/19/64), TEE (5/7/65), DOUBLE PLAY (6/15/66), MIDI MIST (6/26/67), and POD (10/29/69), the primary release was detected off site but the secondary release was detected on site only. The column titled "Radioactive Release (Ci @ R+12 hr)" in Appendix Table B.4.b contains the sum of primary and secondary releases for each of the tests named above. All other listed tests produced only a primary release detected off site.

Appendix Table B.4.a lists 13 tests not designed to be contained which were detected off site. Included are 8 cratering tests, 4 surface tests, and 1 tower test. Appendix Table B.4.b lists the 30 tests which produced accidental releases and 7 tests which produced other releases detected off site. Other releases include three operational releases and four controlled releases from tests which were contained at test time; see the glossary for definitions of these releases. Detailed information on these releases can be found in Reference [5].

Research to perfect underground testing techniques began in 1957 and continued through 1992 even though results achieved in underground containment improved dramatically in the 1970s. Following the BANEBERRY (12/18/70) release, the AEC changed the procedures used to assure containment. Since 1970, releases of radioactivity detected off site were associated with 5 of 385 tests. Of the five, DIAGONAL LINE (11/24/71) and RIOLA (9/25/80) releases resulted from failure of the containment design, MISTY RAIN (4/6/85) and MIGHTY OAK (4/10/86) releases resulted from controlled tunnel purges, and the GLENCOE (3/22/86) release was an operational release during drillback operations [5]. These five tests account for all releases detected off site since 1970. Total radioactivity of these five releases amounted to about 43,500 Curies (at R+12 hr) of primarily inert gases. (For comparison, the BANEBERRY release was estimated at 6,700,000 Curies of gross fission

products.) These release estimates refer to the total radioactive effluent release, not to the amount detected off site.

Identifying a test as "atmospheric" or "underground" should not be used as an indicator that radioactivity from the test was or was not detected off site. With a few exceptions, all nuclear tests conducted at the NTS prior to September 15, 1961, released radioactivity detected off site. On the other hand, also with some exceptions, tests conducted at the NTS since September 15, 1961, did not produce uncontrolled releases of radioactivity. Since the early days of nuclear testing, scientists have improved their ability to detect radiation at remote locations. Some of the early tests, from which radiation was detected on site only, might have been detected off site using the more sophisticated instruments available today. Table 4 summarizes information regarding all 50 tests which released radioactivity detected off site after September 15, 1961. Selected details regarding tower, surface, and crater tests appear in Appendix Table B.4.a; these tests were not designed to be contained. Details regarding shaft and tunnel tests appear in Appendix Table B.4.b.

Categorizing the yield in kt as "less than 20" and "20 to 200" is in conformance with reporting policy established by the AEC. Categories in use since March 1976 are "less than 20 kt," "less than 150 kt," and "20 to 150 kt."

TABLE 4. TESTS WHICH RELEASED RADIOACTIVITY DETECTED OFF THE TEST RANGE COMPLEX 1961-1992, BY LOCATION OF BURST AND BY YIELD RANGE

Location	Yield Range, kt: Less than 20	Yield Range, kt: 20 to 200	Test Totals
Tower	1	0	1
Surface	4	0	4
Crater	5	2	7
Shaft	23	3	26
Tunnel	12	0	12
Totals	45	5	50

Abstracted from [3] and [5].

2. Nuclear Propulsion Systems

Nuclear rocket and ramjet propulsion systems were developed and tested at the NTS from 1959 through 1969. These systems used nuclear reactors that did not involve nuclear explosions. Reactor tests did not produce mushroom clouds or dusty stems, but radioactive material was released into the atmosphere. Hundreds of separate test runs were conducted;

most of them were facility and equipment checks which did not generate power (and therefore no radioactive effluent). Thirty-five test runs released radioactive effluent detected beyond the borders of the Test Range Complex. The total quantity of radioactive materials released during the ten-year period very roughly approximates one atmospheric test of about 30 tons (0.015 kt) TNT energy equivalent release.

3. Nuclear Tests at U.S. Continental Locations Away from the NTS

The first nuclear test by the United States was accomplished at Alamogordo, New Mexico, on July 16, 1945, more than five years before the NTS was established. The radioactive cloud from this atmospheric test was tracked from the test location for several hundred miles over the New Mexico desert.

The AEC conducted 11 underground nuclear detonations at nine U.S. locations away from the NTS between 1961 and 1973. Summary information on these detonations is presented in Appendix Table B.5. One detonation (GNOME) resulted in a release of airborne radioactive material detected outside the testing location.

C. RADIATION PROTECTION, MONITORING, AND EXPOSURE

1. General Radiation Protection Standards

The permissible exposure to ionizing radiation must be considered from both short- and long-term perspectives. In the short term, harmful effects are noted only at substantial exposure rates; this relationship is considered in setting occupational standards. Some scientists believe that long-term harm, such as from cancer, can occur at radiation levels approximating natural background. In their view, the ideal goal would be to eliminate unnecessary exposure from manmade radiation (irradiation for medical purposes may be considered necessary); this relationship is considered in setting general population standards. Radiation protection standards have been developed by such entities as the International Commission on Radiological Protection (ICRP), the National Committee on Radiological Protection and Measurements (NCRP), the Federal Radiation Council (FRC), and the AEC and its successor agencies. The standards developed represent a compromise between the ideal goal, which would ban all uses of radiation, and an achievable goal expressed in terms of acceptable risk, which would continue to allow beneficial uses of technologies that generate radiation.

Monitoring of personnel for radiation exposure has been an ongoing concern since the early 1900s. Up to the 1930s, scientists had not agreed on the upper limits of radiation

exposure that could be permitted, and the available measuring devices were adequate in only a broad sense. Permissible levels of exposure were established in 1934 by the ICRP and NCRP and since then have changed as new information became available. Table 5 indicates the acceptable exposure levels since 1934. The successive lowerings represent improved compromises between the goal of zero excess exposure and the capability of industries to function with occupational exposures at these lower levels.

Federal radiation protection standards that apply to the general population are also presented in Table 5 for comparison with occupational standards. Note that the recommended maximum annual dose to an individual in the general population is one-tenth of the occupational level. This difference illustrates the compromise mentioned above. The lower limits to individuals in the general population recognize the concern of scientists about radiologically sensitive portions of the population. The higher occupational limits recognized the willingness of individuals to work in industries where a higher personal risk may be associated with exposure to radiation. This trade-off is based on the belief that society benefits from the many uses of radiation.

TABLE 5. GENERAL RADIATION PROTECTION STANDARDS

Permissible Occupational Annual Exposure	(rem* per person)
Prior to 1934	100
1934-1950	60
1950-1956	15
1956-Present	5
General Population Standard May 1960 - November 1990	
Mean Annual Dose for Uncontrolled Population	0.17
Maximum Annual Dose for Individuals	0.5
Mean 30-Year Cumulative Dose	5
1990 ICRP Recommendation (ICRP 60)	0.1

* The term "rem" was not used in the early years; the values shown have been restated as approximate rem equivalents. From References [6], [7], and [8].

2. Radiation Monitoring Related to Nuclear Testing at the NTS

By the time nuclear testing began in Nevada, guidelines for exposure had been established and radiation measuring devices were adequate to monitor for compliance with the guidelines. Radiation monitoring was provided to locations both on and off the NTS. In

general, occupational standards applied to on-site workers and, as shown in Table 5, these standards were reduced by one-third during the era of atmospheric nuclear testing. Standards that applied to off-site populations cannot be stated as simply. No independent body of experts had made recommendations regarding permissible levels of radiation from nuclear tests, and the whole question of radiation exposure was undergoing critical review during the early 1950s. In the absence of formal standards, the AEC applied occupational standards to off-site populations. Initially, the 0.3 rem per week set in 1950 was interpreted to be the same as 3.9 rem per quarter; later this was reduced to 3.9 rem per year. An additional limitation of 10 rem to any community within a 10-year period was recommended in 1956. In general, the radiation protection standards applicable to off-site populations were not clearly stated in the early testing years; however, they were not higher than the occupational standards.

a. **On-Site Monitoring**. On-site monitoring during the tests of 1951, 1952, 1953, and 1955 was performed by military personnel working with staff from the Los Alamos Scientific Laboratory. Reynolds Electrical & Engineering Co., Inc., became involved in on-site monitoring in July 1955. Occupational exposure guidelines generally have been observed for employees at the NTS since nuclear testing began. Some exceptions were made for employees in critical jobs such as pilots of cloud sampling aircraft, scientists making early recovery of important experiments, and radiation monitors accompanying others into contaminated areas.

b. **Off-Site Monitoring**. Until the end of the 1953 test series, the Los Alamos Scientific Laboratory, the U.S. Public Health Service (PHS), and/or military units performed off-site monitoring. Before each test, monitors were stationed at strategic locations surrounding the test site. After the detonation, each monitor in the fallout sector would make measurements of radiation exposure levels at these locations and at intervals along assigned roads in the area. The strategy and procedures for detecting radioactive material off site were improved with the passage of time. Increasing sophistication of instruments placed in aircraft made it possible to detect the deposition of fallout over areas without roads. Monitors on the ground were provided with two-way radios so they could be directed to locations where they were needed. These procedures were used to improve knowledge of where fallout was occurring, how much radioactivity was in the fallout, and where the cloud was headed. Established procedures continued to be used when testing was moved underground in the

early 1960s and remained in effect throughout the era of underground nuclear testing. As underground testing progressed, off-site contamination became rare. Even so, to the end of testing in September 1992, ground monitors were at their stations prior to each underground test, and tracking aircraft were in the air in case an accidental release of radioactive material occurred.

In 1955, the PHS was given the responsibility for monitoring radioactivity off site in areas within 200 miles of the NTS. This task continued; however, the PHS mission and personnel were transferred to the U.S. Environmental Protection Agency (EPA) in 1970, and the work was performed by the EPA's Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas, Nevada. The routine monitoring network and procedures were based on early experience and included regular measurements of external ionizing radiation levels and collection of air, water, and milk samples within about 200 miles of the test site. In addition to this routine monitoring, the EPA conducted special monitoring in association with each nuclear test and was prepared to trace radioactivity over a broad area in the event of an accidental release of radioactive material.

3. Estimated Exposure Resulting from all Tests at the NTS

Starting with the first tests at the NTS, data collected by off-site monitors were routinely plotted on a map for each test depositing measurable fallout off site. Some tests of low yield and some conducted at substantial altitude deposited no local fallout. Some tests generated so little fallout that a pattern could not be constructed. Altogether, 75 fallout pattern maps were constructed for 77 tests through 1968. (In two cases, one map was constructed for two tests conducted only hours apart.) Typically, fallout pattern maps were constructed to show lines of equal exposure rate (isolines). Maximum exposure rates, occurring near the NTS, might be shown by an isoline labelled 100 milliroentgens per hour (mR/hr) at a given time, such as 12 hours after detonation. The lowest isolines, occurring at the edges of the pattern, might be shown as 0.5 mR/hr. Intermediate isolines would appear between the highest and lowest isolines with each line positioned to show the exposure rate at that location.

Fallout pattern maps were used to construct cumulative exposure maps. The value for the rate of radiation exposure at three feet above the ground was converted to a value representing the radiation exposure a person could receive if living at that location. By adding the radiation exposure from each nuclear test affecting a given location, it was possible to estimate the cumulative radiation exposure at that location. This process was followed for

all locations where measurements were made and for all atmospheric tests depositing fallout within about 200 miles of the NTS; more distant locations were not included in early efforts to characterize exposure because of the generally low radiation levels beyond 200 miles. A single map portraying the cumulative estimated exposure for all locations was generated by adding together data from individual maps.

Fallout deposition was not uniform in all directions from the NTS. More fallout was deposited in areas northeast and east of the NTS than in other directions as shown by the estimated exposures in Figure 1. In general, measured radiation decreased with distance from the test site, with radiation exposure rates usually falling to only slightly above natural background within about 200 miles. The cumulative estimated exposure falls from 10 R near the NTS to less than 1 R within 200 miles in all directions except due east where a narrow band of elevated exposure levels continues for an unknown distance. In the area where the 1-R line is represented by dashes (the Grand Canyon), no measurements were made due to the rough terrain and the absence of roads and people. No levels as high as 1 R were measured to the southwest of the test site.

The contour lines in Figure 1 represent the total estimated exposure at a given location to which a person could have been subjected if the person had lived at that location from 1951 through 1969. The contour lines do NOT represent potential exposure at the present time. These estimates assumed that persons spent some time indoors where they were partially shielded from the full effect of the fallout radiation. The majority of the exposure would have occurred during the first week following deposition (for each new deposition), and the rate of exposure would have decreased from then on. Radionuclides with a long half-life are still present in the environment but at a very low activity level.

During the era of atmospheric nuclear testing, guidelines were established to limit the amount of radioactive fallout permitted in populated locations. Fallout maps as represented by Figure 1 were constructed to assess the cumulative exposure to these populations. To avoid exceeding the guidelines, restrictions were then imposed on the detonation of nuclear explosions in order to enhance control of the direction that fallout clouds would take. Also, tests were delayed until weather conditions were acceptable, that is, until conditions were such that the predicted fallout pattern would miss nearby population centers.

The 75 fallout pattern maps discussed previously were reviewed for this report to determine how many times each community was within a fallout pattern (without reference to the level of activity). Selected results of this review are presented in tabular form on Figure 1.

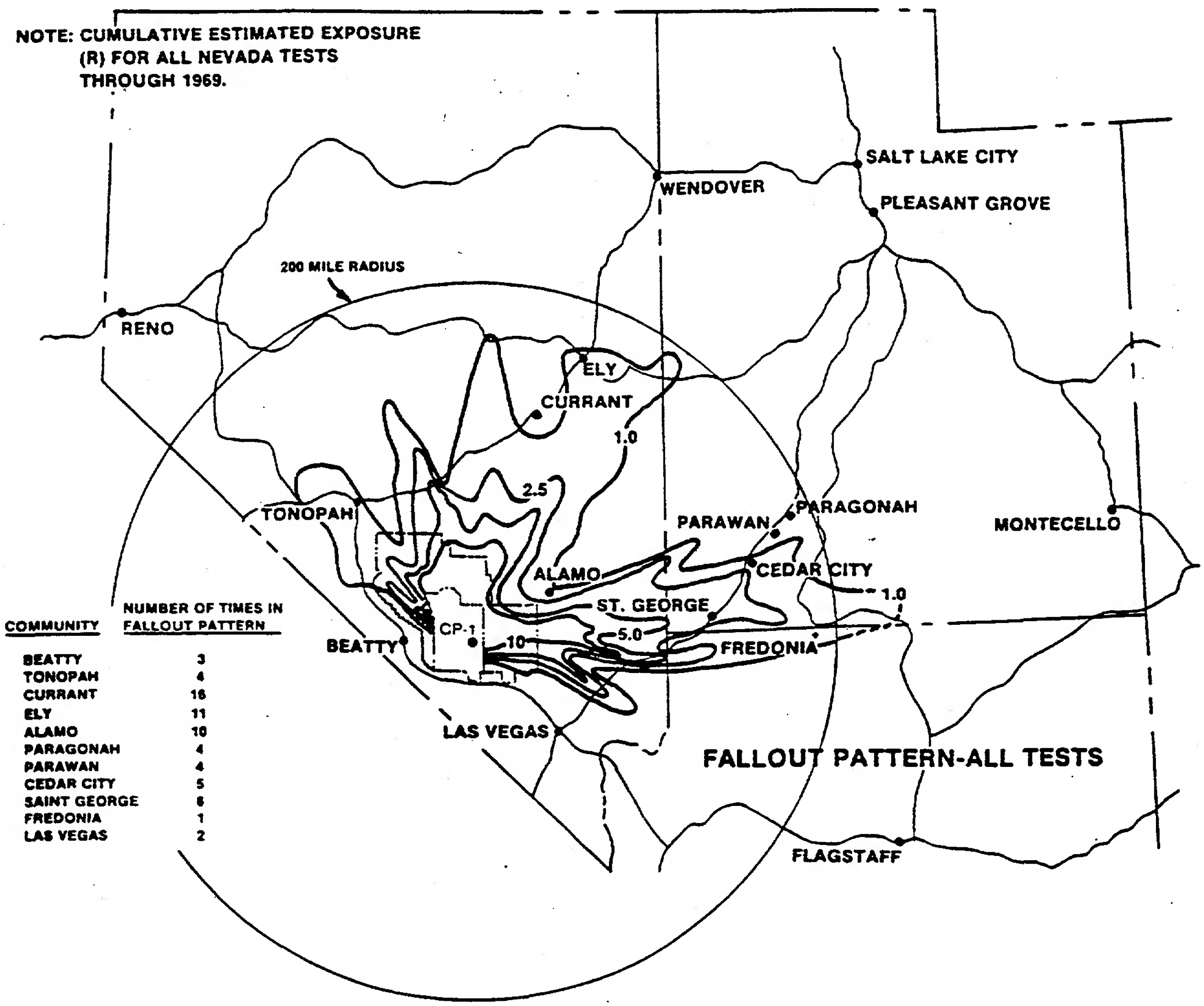

Figure 1. ESTIMATED EXPOSURE MAP

Some communities received low levels of fallout in addition to the number of times shown in the table; these occurrences are not included because the level of radiation was below the lowest isoline of the established fallout pattern.

A given estimated population exposure can be realized from two vastly different levels of exposure. First, there could be a relatively large exposure to a small population producing a given total population exposure. Second, there could be a relatively small exposure to a large population producing the same total population exposure as in the first case. Also, the exposure could occur as a single event or could be the cumulative result of a series of events; the latter is distinguished from the former by stating the exposure as "cumulative." All of these situations occurred during the period of atmospheric testing. For example, the 14 residents of Riverside, Nevada, received an estimated exposure of 7 to 8 R (about half the permissible annual amount) from the SIMON test fallout in April 1953. The estimated population exposure was, therefore, about 112 person-R (8 x 14 = 112). On the other hand, the cumulative exposure from all tests at the NTS was about 0.08 R per individual at Lone Pine, California. The average population during the period of exposure was about 1,400 persons, so the cumulative estimated population exposure was also about 112 person-R (0.08 x 1400 = 112). (These data are approximations used to illustrate the concept; numbers of people and exposures received are not known exactly.)

The 120 tests conducted during the 1950s have been reevaluated in terms of contribution to off-site population exposure. Of the 120 tests, 12 released no radioactive material at all, 13 released radioactive material detected on site only, 78 are not suspected of contributing substantially to estimated cumulative population exposure, and 17 each contributed in excess of 1,000 person-R to estimated cumulative population exposure. Table 6 presents selected details for these 17 tests which account for about 80 percent of the estimated cumulative population exposure in the region where estimates can be made [9].

Several relationships may be noted from the data in Table 6. In general, these were tests of about 10 kt or more with the device placed on a tower. With this configuration, the fireball would contact the earth's surface, so more soil and debris would be vaporized and sucked into the mushroom cloud than would be the case with higher or smaller detonations.

Other tests which also met these two conditions (relatively large and close to the ground) were not prime contributors because they were conducted when weather conditions were such as to deposit the fallout thinly in relatively unpopulated areas. Thus, the population exposures from these tests were relatively low. These generalizations do not necessarily apply to specific residents in the downwind area during the period of atmospheric testing.

TABLE 6. CONTINENTAL NUCLEAR TESTS CONTRIBUTING IN EXCESS OF 1000 PERSON-R TO ESTIMATED CUMULATIVE POPULATION EXPOSURE, 1951-1958

Test Name	Date	Type	Height (Feet)	Yield (kt)	Collective Estimated Exposure, (person-R)
EASY	5/07/52	Tower	300	12	2,700
FOX	5/25/52	Tower	300	11	1,800
ANNIE	3/17/53	Tower	300	16	3,700
NANCY	3/24/53	Tower	300	24	1,800
BADGER	4/18/53	Tower	300	23	2,100
SIMON	4/25/53	Tower	300	43	2,200
HARRY	5/19/53	Tower	300	32	30,000
BEE	3/22/55	Tower	500	8	11,000
MET	4/15/55	Tower	400	22	1,200
APPLE-2	5/05/55	Tower	500	29	1,700
ZUCCHINI	5/15/55	Tower	500	28	2,300
BOLTZMANN	5/28/57	Tower	500	12	2,200
DIABLO	7/15/57	Tower	500	17	2,700
KEPLER	7/24/57	Tower	500	10	1,500
SHASTA	8/18/57	Tower	500	17	2,600
SMOKY	8/31/57	Tower	700	44	7,500
WHITNEY	9/23/57	Tower	500	19	1,300

III. RADIATION EFFECTS ON HEALTH

A. PERSPECTIVE

The potential hazards to public health from exposure to ionizing radiation from atmospheric weapons testing became a significant public concern in the 1950s. Until then, only a limited number of nuclear detonations had occurred and such scientific studies as had been conducted focused primarily on the Japanese exposed to the nuclear explosions at Hiroshima or Nagasaki. After tests in Nevada in 1953 and in the Pacific in 1954, public awareness increased to include concern about the possible hazards from regional and world-wide fallout and its effects on people. The Joint Committee on Atomic Energy of the U.S. Congress conducted many hearings between 1955 and 1963 to gather information on possible health risks from radiation and to receive testimony regarding the quantities and distribution of global fallout. These hearings and the publicity they received contributed to even greater public awareness of possible radiation hazards from fallout.

Two independent series of scientific reports document the complexities of determining the effects of ionizing radiation on human well-being. The National Academy of Sciences - National Research Council Committee on the Biological Effects of Atomic Radiation published several reports from 1956 to 1961. These were followed in 1972 by a report [7] of the Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR Committee) which deals with the scientific basis for the establishment of radiation protection standards and encompasses a review and reevaluation of scientific knowledge concerning radiation exposure of human populations. Recent works of this Committee were published as the BEIR IV [10.a] and BEIR V [10.b] reports. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has released ten substantive reports since 1958 regarding radiation exposure and radiation effects. Recent UNSCEAR reports were published in 1982 [11.a] and 1988 [11.b].

Determining the human health effects from exposure to ionizing radiation is complex because of the many interrelated facets to be considered. The most important factor is the actual dose received. Effects will vary depending on the length of time over which the dosage accumulates. Some effects are observed within a few weeks from prompt (short duration) exposures to hundreds of R; these are known as acute effects. Other effects may not be observed for many years; these are known as latent effects. The predictability (and basis for suspicion) of an effect depends upon assumptions regarding the exposure-response relationship. Some scientists believe there is no response below a certain exposure (the

threshold hypothesis), while others believe any exposure, no matter how low, may elicit a response (the linear hypothesis). Health effects, such as the incidence of leukemia, will peak in a few years following exposure, while some cancer effects may not be observed for 30 years or more. To complicate matters further, radiation-caused cancer in a given body tissue cannot be distinguished from a cancer in the same tissue caused by some other stimulus. Cancers in the breast, thyroid, lung, and blood-forming tissue of the bone seem to have the strongest association with radiation exposure [10.a].

Human responses to given doses of radiation are well documented for acute exposures above 25 R, but for exposures below 25 R, the evidence of human response is inconclusive. Documentation has come from medical follow-ups of atomic bomb survivors in Japan, of Marshallese accidentally exposed to fallout in 1954, of accidentally-exposed workers in the nuclear industry, and of individuals who received radiation treatment for medical purposes. Immediate effects such as nausea and diarrhea begin to appear in people exposed within the range of 100 to 200 R. All exposed people will get sick following an acute exposure of about 200 R, and some might die [4]. Subtle effects, such as changes to blood cells, have been observed at acute exposures as low as 25 R, and by use of modern technology, chromosomal effects can be detected in white blood cells following exposures as low as a few R.

The Test Manager's Committee to Establish Fallout Doses (TMCEFD) estimated fallout radiation exposures for population groups residing within 200 miles of the NTS. These estimates were well below 25 R [9]. The TMCEFD estimated the population of this area to be about 210,000 individuals between 1951 and 1958. Of this number, about 90 percent (189,000 persons) received less than 1 R cumulative estimated exposure from fallout; about 9 percent (18,900 persons) received between 1 R and 6 R; the remainder (2,100 persons) received between 6 R and 14 R; and the largest cumulative estimated exposure known, about 14 R, was received by one person. (As shown earlier, the federally recognized permissible occupational exposure from 1950 to 1956 was 15 R per year.)

Numerous studies have been conducted to develop an understanding of health effects from low-level ionizing radiation. Some of the studies examined data dealing with large populations of workers at facilities handling radioactive materials [12] while others were concerned with smaller populations accidently exposed to fallout radiation [13]. A 1982 report to the Congress by the Comptroller General of the United States evaluated several studies of the exposure/ response relationship. This General Accounting Office (GAO) study considered the scientific questions about the cancer risks of low-level ionizing radiation exposure. The stated objectives were to (a) determine what definite conclusions, if any, could

be drawn from current scientific knowledge and (b) determine what conclusions could be drawn about the best direction for current and future research. With respect to the first objective, the study group reported, "... there do not appear to be very many definite conclusions that can be drawn about the cancer risks of low-level ionizing radiation exposure." [14]

The report notes further that studies and recommendations which could have been helpful have resulted in considerable controversy within the scientific community. With respect to the second objective, the GAO recommended legislation giving statutory authority to an interagency committee to coordinate federal research on the health effects from exposure to ionizing radiation.

After reviewing and reanalyzing a number of recent studies on the question, the first conclusion of the GAO study is that "There is as yet no way to determine precisely the cancer risks of low-level ionizing radiation exposure, and it is unlikely that this question will be resolved soon." (14)

The executive summary of the BEIR V report states:

> Carcinogenic effects of radiation on the bone marrow, breast, thyroid gland, lung, stomach, colon, ovary, and other organs reported for A-bomb survivors are similar to findings reported for other irradiated human populations. With few exceptions, however, the effects have been observed only at relatively high doses and high dose rates. Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated natural background radiation, have not shown consistent or conclusive evidence of an associated increase in the risk of cancer. [10]

B. UTAH HEALTH STUDIES

Studies conducted in Utah since 1961 of the relationship between fallout and health help illustrate the problem of reaching definite conclusions. The studies dealt with deaths from leukemia and with the occurrence of thyroid problems among children.

1. Leukemia. Studies began in 1961 of possible excessive leukemia deaths in Washington and Iron Counties, Utah, which might have resulted from NTS weapons tests fallout radiation. Initial data indicated there was an excessive number of leukemia deaths in these counties in 1959 and 1960 compared to the number of deaths expected based on rates found in the rest of the United States. Reviewers subsequently pointed out that when the data were analyzed by date of onset rather than date of death, the clusters in 1959 and 1960 were no longer apparent. The final study results, which were not published at that time, indicated there was an excess of leukemia deaths in southwestern Utah, but there was no

evidence to associate these cases with fallout exposure, other environmental contaminants, or hereditary aspects [15, 16].

Other so-called "leukemia clusters" in Utah were identified in Monticello for the period 1956-65, in Parowan and Paragonah during 1965-67, in Pleasant Grove during 1965-67, and in South Salt Lake City during 1968-71. In Arizona, clusters were identified in Fredonia during 1960-65 and in Flagstaff for the period 1960-71. Each of these "clusters" was investigated when it was brought to light. The investigations often involved the Communicable Disease Center (the federal CDC, now the Centers for Disease Control and Prevention), which was trying to determine if some forms of leukemia were caused by a virus. (The CDC investigated "leukemia clusters" nationwide, not only in the Utah area.) The investigation of each of the Utah incidents left some questions unanswered, and in no case could investigators establish a relationship with fallout radiation. Among the unanswered questions was the matter of how much radiation the leukemia victims and other residents of the same communities actually received; individual exposures had not been measured or estimated.

Studies have continued of the possible link between fallout and leukemia deaths in Utah. One study, published in the New England Journal of Medicine in February 1979 [17], reviewed all childhood cancer deaths in Utah for the period 1944-75 and categorized them by place of residence and by age during the period 1951-58 (for those born after 1950). The study indicated that the number of leukemia deaths was 2.4 times larger in the "high exposure" area than in the "low exposure" area and was greatest among children aged 10 to 14. However, in the same issue of the Journal, a reviewer from the National Cancer Institute comments that data for childhood cancers other than leukemia also indicate an interaction between fallout level and exposure, equal in size but opposite in direction to that observed for leukemia. He states:

> It is unlikely that radioactive fallout from the Nevada weapons tests caused both an increase in leukemia mortality and a decrease in deaths from other childhood cancers; yet this is a possible interpretation of the results of the above analysis. [18][4]

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[4] Subsequent review of the death certificates used in the original study found five miscoded benign tumors; correction of these errors reversed the "equal but opposite" relationship. This quote has been retained to preserve the historical sequence in the revisions of this fact book.

The reviewer then recommends caution in the interpretation of the reported study and suggests that additional studies be conducted in a manner to include consideration of other important factors which could have a bearing on the conclusions reached.

Data comparable to that used in the 1979 study—available at the National Cancer Institute—has been analyzed since 1979 using slightly different methodology. In the 17 southern "high-fallout" counties of Utah, the leukemia mortality rate (4.1 deaths per 100,000 people per year) for the period 1951-78 was slightly, but not significantly, lower than for the 12 northern "low-fallout" counties in Utah (4.25/100,000). Rates for the entire United States (3.99), Eastern Oregon (3.52), and the state of Iowa (3.79) do not differ significantly (in a statistical sense) from the two rates shown for Utah. The researchers concluded that the increase of childhood leukemia as observed in Utah also occurs in other locations where fallout is not considered as a causative factor [19].

Other investigators have pursued the question of leukemia incidence in Utah; their results are not in agreement. One study indicated a 340 percent excess mortality from leukemia [20]. Another study indicated the excess was 54 percent [21]. (The magnitudes of these percentages may be deceiving because they are based on small numbers where a change of one unit can cause a large percentage change.) The latter study indicates 5 excess leukemias in the 0 to 14 age group during the period 1955-1980. No indication of excess leukemias appeared in the 15 to 49 age groups, but up to 14 excess leukemias may have occurred in the over-50 age group (an excess of 8 compared to the leukemia mortality rate in the United States). Leukemia accounted for 1,419 deaths during the period 1950-80 among Utah residents born before 1958. There is no presently known way to identify which possible 14 out of 1,419 leukemia deaths could be related to radiation exposure.

The University of Utah conducted an extensive case-control study during the late 1980s of leukemia deaths in Utah for the period 1952-81 and exposure to radioactive fallout from the NTS for the period 1952-58. Part of the conclusions section states:

> In view of the consistency with other literature and the lack of other plausible explanations, we conclude that the excess in southwestern Utah is probably not due to chance and may be attributable to fallout. However, the estimated number of cases from fallout in this region is small (about 7 out of a total of 17) and these cases are indistinguishable from those caused by other factors ...
>
> If the linear dose-response hypothesis is correct, this would imply that about 50 leukemias throughout the rest of the state also were attributable to fallout. However, as the background incidence is about 900, this excess is undetectable against the natural variation in leukemia rates.

Attributable risks in this group would be very low (about 6%) and, as in southwestern Utah, the radiogenic cases would be indistinguishable from those with other causes. [22]

2. Thyroid Diseases. Investigation of the possible relationship between fallout in Utah and thyroid disease began in 1962 when milk was found to be contaminated with radioiodines from nuclear detonations in Nevada [23]. The level of radioiodines found in the milk was sufficient to cause some medical researchers to estimate that excess thyroid cancers might appear in children who were under two years old at the time of exposure. (A child's smaller thyroid gland, compared to that of an adult, would receive a larger radiation dose from a given concentration of radioiodine in milk. Also, a child's growing tissue is thought to be more sensitive to radiation than is mature tissue.) The initial study of all cases of thyroid surgery in Utah and Nevada during the period 1948-62 indicated a relatively constant annual rate over the 15 years. Noting the prolonged period between exposure and a detectable response, the researchers concluded that later follow-up studies would be more likely to demonstrate a relationship between fallout radiation and the rate of thyroid or related diseases [16].

A study was begun in 1965 of the prevalence of various thyroid diseases among several thousand schoolchildren living in southwestern Utah, neighboring areas of Nevada, and a town in Graham County, Arizona, selected as a suitable control. Examinations were conducted annually from 1965 through 1971. Study results were published in 1971 for the period 1965-68 [24] and in 1974 for the entire study [25]. A total of 4,818[5] children were examined, and no difference was found in rates of any category of thyroid disease between children presumed to have been exposed to high fallout in the early 1950s and those not so exposed.

During the period 1985-87, a University of Utah medical team conducted a follow-up study of the 4,818 subjects examined from 1965 to 1971. The research team found 4,183 of the earlier participants and 3,122 of these were examined for thyroid abnormalities. In general, the research team concluded that thyroid abnormalities were more prevalent among females than among males, that the prevalence increases with age, and that the difference in prevalence between "exposed" and "non-exposed" groups was, at most, marginally significant. Reporting in a special issue of the Health Physics Journal, the investigators state:

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[5] The number of examined subjects had earlier been reported as 5,179 due to an error of double counting.

> Based on the rates of thyroid neoplasms in the two geographic locations, we conclude that living near the NTS in the 1950s has not resulted in a statistically significant increase of thyroid neoplasms in subjects from Utah and Nevada when compared with subjects of the same age and gender living in Arizona. [26]

Researchers at the University of Utah continued their examination of collected data and revised their findings. The final report states:

> In conclusion, there is a statistically significant dose-response relationship ($p=0.022$) between exposure to radioiodines resulting from open-air nuclear weapons testing at the NTS and the occurrence of thyroid neoplasms, including both carcinomas and benign neoplasms, in a cohort of schoolchildren living in areas downwind of the testing. The association for thyroid carcinomas alone was not statistically significant but was consistent with the results for all neoplasms. Due to the small numbers of cases and the possibility of a covert bias in the examination of subjects, it is difficult to be certain at this time whether the apparent dose-response relationship is truly causal. Further follow-up of the cohort identified in this study is needed in order to establish a causal relationship. [27, p. 235.]

Continued investigation, as suggested in the last sentence, is uncertain at this time.

IV. LITIGATION AND LEGISLATION

A. SUMMARY OF LITIGATION

Interest in the atmospheric testing days was brought to the forefront in 1977 when several suits were brought by the survivors of certain military personnel against DoD claiming leukemias resulting from excessive radiation exposure to observers of the SMOKY test of August 31, 1957. These claims received nationwide media attention. Shortly after, numerous claims were filed against the U.S. government by residents of southern Utah, northern Arizona, and southern Nevada. At about the same time, the Governor of Utah launched a full-scale investigation on behalf of the residents of that state, and congressional committees held new hearings into allegations of harm from off-site radiation exposure. The hearings were held during 1979 in Salt Lake City, Utah; Las Vegas, Nevada; and Washington, D.C.

Three notable cases have come to trial since the 1979 hearings. The first, an attempt to reopen a 1956 trial, is known as the "Bulloch" case. The second, a class action suit involving 1,192 plaintiffs, is known as the "Allen" case. The third, a class action suit involving 216 employees of NTS contractors, is known as the "Prescott" case.

In the "Bulloch" case, several Utah sheepmen alleged that two nuclear tests in the spring of 1953 were associated with the deaths of sheep in flocks wintered on the range north and northeast of the NTS. Owners of the flocks claimed that an excessive number of sheep died with peculiar symptoms after being exposed to fallout from the NANCY test on March 24 and that conditions were made worse by fallout from the May 19 HARRY test conducted shortly after completion of shearing and lambing at the home base near Cedar City, Utah. The sheepmen, unhappy with the conclusions of investigations conducted during June to November 1953, filed tort claims against the government in 1955 claiming the AEC was responsible for the excessive sheep deaths. The suit was decided in favor of the AEC in October 1956 [28].

During the 1979 congressional hearings, a former employee of the AEC submitted a report to the congressional committee wherein he asserted that the sheep deaths represented in the "Bulloch" case most likely were caused by radioactive fallout from the NANCY and HARRY tests. As a result of these assertions, the "Bulloch" case was reopened in June 1981 to examine the narrow issue of fraud being committed on the court during the 1956 trial. The U.S. District Judge in Salt Lake City determined that the government had committed fraud by withholding information from the court [29]. The Tenth Circuit Court of Appeals, first in a decision by a three-judge panel in November 1983 [30], and later sitting as the entire court in May 1985, overturned this decision, stating:

> As mentioned, the trial court concluded in Bulloch II that there had been a fraud on the court (the same judge) in Bulloch I. In so doing, the court seems to have placed much, if not controlling, weight on the hereinabove described development (prior to Bulloch I) of the opinions of the veterinarians during the course of the investigations. We have considered this carefully (with the other factors raised by the trial court) and must conclude that nothing was demonstrated which would constitute fraud on the court. [31]

In the "Allen" case, 1,192 claims against the government were grouped together for presentation to the Federal District Court in Salt Lake City, Utah. Attorneys selected 26 individuals (later reduced to 24) to represent the commonly alleged injuries and deaths from fallout. Plaintiffs alleged that the AEC was negligent in conducting atmospheric nuclear tests at the NTS; specifically negligent in not providing for protection of civilians. The trial was held in Salt Lake City from September to December 1982. The court's decision [32], released in May 1984, denied negligence by the AEC in conducting the tests but affirmed negligence by the AEC in providing protection to the off-site population. Ten plaintiffs were awarded compensation but the court denied the claims of the other 14 on the grounds of causation. Survivors were awarded compensation for nine "wrongful deaths"--eight from types of leukemia and one involving breast cancer. Compensation was also awarded for one thyroid cancer that the judge ruled "was more likely than not" caused by exposure to fallout. These forms of cancer have previously been linked to radiation exposure.

The Allen decision was appealed by the government. Upon review, the appeals court unanimously reversed the lower court's ruling [33] on the grounds that the government could not be held liable because of the discretionary nature of the actions for which it was sued. The appeals court decision was then brought before the U.S. Supreme Court by attorneys for the plaintiffs. The Supreme Court refused to consider the case [34] which, in essence, affirms that the government is immune from lawsuits challenging major public policy decisions.

In the "Prescott" trial, six representative actions (of 216 filed) against the United States were brought before the court alleging negligence by the AEC or its contractors in protecting workers engaged in atmospheric and underground nuclear testing at the Nevada Test Site between January 1951 and February 1981. The decision of the Court addressed several relevant issues:

> The Court finds that Plaintiffs have failed to present persuasive evidence that Defendant, or others responsible for establishing and maintaining radiological safety procedures at the NTS, failed to do so. Indeed, the evidence presented at trial

> persuades the Court that procedures for the radiological monitoring and protection of NTS workers to guard against radiation exposures in excess of the established permissible limits were in place and were followed throughout the time frame during which Plaintiffs were employed at the NTS.
>
> * **
>
> ... Plaintiffs have generally failed to prove the eight specific acts of negligence attributed to Defendant.
>
> * **
>
> The Court finds that Plaintiffs have failed to prove by a preponderance of the evidence, AND TO A REASONABLE DEGREE OF MEDICAL PROBABILITY, that the radiation exposures experienced by [Plaintiffs] were a substantial contributing factor in causing their cancers. (Emphasis added in the original source.)
>
> * **
>
> The Court has concluded that Plaintiffs have failed to prove their negligence claims, and that to the extent they may be deemed to have done so, their claims are barred by the discretionary function exception to the FTCA (Federal Torts Claims Act). [35]

Other groups of claimants in northern Utah also filed suit against the government alleging injury from fallout radiation originating at the NTS. These cases involved residents in Duchesne County (the "Timothy" case) and Utah County (the "Farley" case). These and many additional claims against the government have been dismissed by the courts.

B. <u>SUMMARY OF HEARINGS AND LEGISLATION</u>

Committees of the U.S. Congress have conducted hearings at various times since 1955 on nuclear weapons testing, radioactive fallout, and radiation effects on health. The subject of interest at these hearings is indicated by the titles listed on the next page. Recent hearings have prompted submission of a number of bills designed to compensate individuals for alleged injuries resulting from low-level radiation.

Efforts in the political arena to gain compensation for alleged fallout victims continued along a tortuous path through the decade of the 1980s. These efforts seemed to reach an end in the fall of 1990. (Special legislation was passed during the 1980s to provide certain medical benefits to veterans.)

Early legislation categorized claimants into four broad groups: government contractor employees who worked "on-site" (at the NTS and other locations), residents in the off-site areas ("downwinders"), military personnel who participated in military exercises at the NTS (and at Pacific sites), and uranium miners (who are treated differently from the others). On October 15, 1990, President Bush signed legislation (Public Law 101-426) to compensate "downwinders" and uranium miners. Downwind claimants could receive $50,000 if they contracted one of the specified diseases and met requirements as to locations and times of residence in fallout areas as specified by the law. Uranium miners could receive $100,000

if they qualify as to years they worked in uranium mines. PL 101-426 was amended by Public Law 101-510 (National Defense Authorization Act for Fiscal Year 1991) which became law on November 5, 1990. One amendment added compensation coverage to any individual who "(C) participated on site in a test involving the atmospheric detonation of a nuclear device." Thus, military servicemen and contractor employees became eligible to receive $75,000 subject to specified restrictions on dates of alleged exposure and contracted illness. Over $200 million has been awarded to claimants in the above four categories as a result of legislation. Claimants do not have to prove a causal connection between any past radiation exposure and any subsequent illness.

SELECTED PUBLISHED CONGRESSIONAL HEARINGS ON FALLOUT AND RADIATION

1955 "Health and Safety Problems and Weather Effects Associated With Atomic Explosions," Joint Committee on Atomic Energy (JCAE), April 1955.

1957 "The Nature of Radioactive Fallout and its Effects on Man," Special Subcommittee on Radiation (SSR) of the JCAE, May and June 1957.

1959 "Fallout From Nuclear Weapons Tests," SSR/JCAE, May 1959.

1959 "Biological and Environmental Effects of Nuclear War," SSR/JCAE, June 1959.

1960 "Radiation Protection Criteria and Standards: Their Basis and Use," SSR/JCAE, May and June 1960.

1961 "Radiation Safety and Regulation," JCAE, June 1961.

1962 "Radiation Standards, Including Fallout," SRD&R/JCAE, June 1962.

1963 "Fallout, Radiation Standards, and Countermeasures," SRD&R/JCAE, June 1963.

1969 "Underground Weapons Testing," Committee on Foreign Relations, U.S. Senate, September 1969.

1977 "Radiation Health and Safety," Committee on Commerce, Science, and Transportation, June 1977.

1979 "Health Effects of Low-Level Radiation," Joint Hearing Before the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, HR, and the Health and Scientific Research Subcommittee of the Labor and Human Resources Committee and the Committee on the Judiciary, Senate, April 1979. No. 96-41.

1979 "Low-Level Ionizing Radiation," Subcommittee on Energy Research and Production and the Subcommittee on Natural Resources and Environment of the Committee on Science and Technology, HR, June 1979 (No. 41).

1979 "Low-Level Radiation Effects on Health," Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, April, May, and August 1979. Serial No. 96-129.

1980 "Radiation Exposure Compensation Act of 1979," Joint Hearing, Subcommittee on Health and Scientific Research of the Committee on Human Resources and the Committee on the Judiciary, U.S. Senate, on S.1865, June 1980.

1987 "Health Effects of Underground Nuclear Tests," Oversight Hearing Before the Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs, HR, September 1987. Serial No. 100-35.

V. SUMMARY AND STATEMENT OF CURRENT EFFORT

The first nuclear weapons were developed by the United States during World War II. These powerful weapons were viewed as a means of ending the war and maintaining future peace. Following the war, tension continued among countries because of perceived threats of communist takeover. The Soviet Union also developed a nuclear capability during the late 1940s. The United States pursued the policy of maintaining nuclear superiority as a deterrent to aggression. Nuclear superiority required advancements in design of nuclear weapons. New designs had to be tested, and time was of the essence. Rapid advancement in design of nuclear weapons is credited in large part to experiments conducted at the NTS.

Tests of nuclear weapons and other devices were conducted in the atmosphere at the NTS because many of the diagnostic procedures required a clear line of sight between the device and the diagnostic instruments. The AEC conducted 120 nuclear tests at the NTS from 1951 through 1958, most of them in the atmosphere.

Some radioactive debris from the nuclear tests was carried by wind to ranches and communities primarily to the north and east of the NTS. Test controllers attempted to limit radiation exposure to off-site populations by using meteorologic conditions to spread fallout over unpopulated areas. Nevertheless, some residents in the downwind area were exposed to radioactive debris. Seventeen of the 120 tests conducted in the 1950s are identified as each contributing in excess of 1,000 person-R to estimated cumulative population exposure to off-site populations. The immediate and long-range health effects of these exposures have been of concern to some downwind residents since the early 1950s.

Many studies investigated the relationship that might exist between exposure to fallout radiation and later health effects. In a 1982 review of such investigations, the GAO observed that studies which could have clarified the relationship were inconclusive and led to controversy within the scientific community. The GAO also noted that any possible relationship between low levels of radiation exposure and cancer defies early resolution.

Recent studies by the University of Utah of leukemia mortality and thyroid abnormalities in the studied Utah populations produced inconclusive evidence of an association between fallout and childhood leukemias or between fallout and noncancerous thyroid nodules. The number of people studied in the "high-dose" region is small, so the observed associations are difficult to interpret with certainty.

Recent congressional hearings focused attention on the era of atmospheric nuclear testing and the fallout legacy and prompted a number of legislators to submit bills designed

to compensate people for alleged injuries resulting from low-level radiation, primarily exposure to fallout. The judicial system also became involved in the radiation exposure-response controversy.

The DOE, established in 1977, inherited both the underground nuclear testing program and the problems resulting from the AEC atmospheric testing program of the 1950s and early 1960s. Numerous claims filed against DOE since 1977 allege injury from fallout radiation. Determination of radiation doses actually received by claimants was considered important to resolution of these claims.

The DOE conducted a major research effort beginning in 1979 to assess radiation doses received by off-site residents. Officially titled "Off-Site Radiation Exposure Review Project" (ORERP), the project had two main objectives. The first was to make relevant data and information available to the public. To this end, the Coordination and Information Center was established in Las Vegas, Nevada. This center, opened to the public in July 1981, has collected about 270,000 documents related to the nuclear testing program and is indexing and preserving these documents in a permanent archive. The second ORERP objective was to produce a reevaluation of off-site radiation doses characterized by region, community, age, and occupation. Dose reconstruction has been accomplished by computer modeling based on data collected by radiation monitors during the era of atmospheric testing and on analytical results of soil samples collected during the 1980s. Results of this dose reconstruction effort are available at the Coordination and Information Center in Las Vegas.

The Utah studies of leukemias and thyroid abnormalities are the most comprehensive attempts to date to find out if a relationship may be identified between estimated radiation doses and these later maladies. Both studies used data results produced by the ORERP (along with independent review, appraisal, and verification of these data) in assigning estimated radiation doses to study subjects.

The second objective of the ORERP, dose reconstruction for resolution of claims, has been overtaken by events in the legislative arena so may no longer be relevant for its originally intended purpose. However, the dose reconstruction methodology has been developed and found useful in this and other applications; extensive review, correction, and evaluation of raw data has been completed; data bases and computerized algorithms generated by the ORERP are available for use by others to apply to other situations to critique or to refine or extend the application.

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(34) Allen v. United States, 108 S. Ct 694 (January 8, 1988).

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APPENDIX A. GLOSSARY

Accidental Release The release of radioactive matter to the atmosphere when the test environment fails to contain all radioactivity following device detonation. Excludes operational and controlled releases.

Atmospheric Test A test conducted aboveground in the open air. Surface tests are usually considered atmospheric because they were not designed to contain radiation.

Cementback Operation whereby the drill hole is sealed with a plug and cemented to the surface.

Controlled Release A planned, filtered release performed to reduce airborne radiation levels in the working environment (as in purging gases from a tunnel prior to reentry).

Dose A measure of the energy absorbed in tissue by the action of ionizing radiation on tissue. The unit of absorbed dose is the rad.

Drillback Drilling operation, performed after test activities have ceased, to sample fission product materials in the test cavity.

Exposure A measure of the ionization produced in air by x or gamma radiation. The special unit of exposure is the roentgen.

Fallout The process or phenomenon of the fall back to the earth's surface of particles contaminated with radioactive material following an atmospheric or uncontained nuclear detonation. The term is also applied in a collective sense to the contaminated particulate matter itself.

Fission The process whereby the nucleus of a particular heavy element splits into (generally) 2 nuclei of lighter elements, with the release of substantial amounts of energy.

Fusion The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, combine to form the nucleus of the heavier element helium with the release of substantial amounts of energy. These are also called thermonuclear reactions because very high temperatures are used to bring about the fusion of the light nuclei.

Gas Sampling Operation to determine levels of noble gases present in a test cavity; usually performed after test activities have ceased.

Half-Life Time required for a radioactive substance to lose half of its activity by decay. Half-lives range from a fraction of a second to many millions of years but are constant for a specific radionuclide.

Ionizing Radiation Electromagnetic radiation (gamma rays or x-rays) or particulate radiation (alpha particles, beta particles, neutrons, etc.) capable of producing ions, i.e., electrically charged particles, directly or indirectly, in its passage through matter.

kt A kiloton. The energy of a nuclear explosion that is equivalent to an explosion of 1,000 tons of TNT.

Late-Time Seepage Leakage of noble gases at test sites after all other operations in the area have ceased.

Leukemia Disease with excess production of white blood cells (leukocytes).

Mushroom Cloud More technically, radioactive (or nuclear) cloud. An all-inclusive term for the cloud of hot gases, smoke, dust, and other particulate matter from the explosion of a nuclear device and from the environment, which is carried aloft in conjunction with the rising fireball. As the cloud rises, the cloud and stem assume the shape typically associated with mushrooms.

Nuclear Device A device designed to produce a nuclear explosion for purposes of testing the design, for verifying nuclear theory, or for gathering information on device performance. Many devices were designed for diagnostic purposes and not as bombs or weapons.

Nuclear Weapon A nuclear device designed to be used as a bomb or weapon in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion, or both.

Nuclide A general term applicable to all atomic forms of the elements; often used incorrectly as a synonym for isotope. Nuclides comprise all the isotopic forms of all the elements.

Off Site Generally refers to any location outside the Test Range Complex as defined below.

On Site On the Test Range Complex as defined below.

Operational Release The unintended release of gases during normal posttest operations (as in a drillback to sample fission product materials in the test cavity, or a cementback to plug and seal a drill hole).

Other Release Any release of radioactivity other than accidental. Includes operational and controlled releases.

Person-R The product of the average individual exposure in a population times the number of individuals in the population. This is the numerical expression of population exposure.

Population Exposure The collective exposure to a population which equals the sum of individual exposures to the members of the population. It is the number of people multiplied by their average exposure.

Radiation The emission and propagation of energy through space or through a material medium in the form of waves and/or particles. Only alpha, beta, gamma, x-ray, and neutron emissions resulting from nuclear detonations and detonation products are intended herein.

Radioactive Of or exhibiting radioactivity.

Radioactivity The property of unstable nuclei of atoms of emitting particles or rays in the process of becoming stable.

Radionuclide A radioactive nuclide. (See nuclide.)

Roentgen (R) A special unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce one electrostatic unit of charge of either sign per cubic centimeter of air at standard temperature and pressure.

Secondary Release The smaller of two or more releases from the same test.

Stem The trail of (primarily) dust or dirt particles beneath a mushroom cloud. The particles are carried upward by the updraft beneath the rapidly rising cloud.

Test Range Complex The government-controlled area that includes the Nevada Test Site, the adjacent Nellis Air Force Range (formerly the Las Vegas Bombing and Gunnery Range), and the Tonopah Test Range.

Tunnel Purge A planned, controlled, filtered release conducted to reduce airborne radioactivity in a tunnel prior to reentry.

Uncontrolled Release A spontaneous release occurring after a test, but before postshot drilling operations commence. This term is used with reference to releases following tests conducted in tunnels.

Venting The escape through the surface to the atmosphere of gases and other residues formed in a subsurface explosion.

Yield The total effective energy released in a nuclear explosion. It is usually expressed in terms of equivalent tonnage of TNT required to produce the same energy release in an explosion.

APPENDIX B. SELECTED DATA FOR NUCLEAR TESTS[6]

The AEC conducted 120 nuclear tests at the NTS from January 1951 through October 1958. These tests have been divided into three subgroups based on yield. Table B.1 presents selected data for 49 tests each with a yield of less than 1 kt; 26 of these produced low levels of radioactivity detected off site. Table B.2 presents selected data for 53 tests each with a yield greater than 1 kt but less than 20 kt, all of which are presumed to have produced radioactivity detectable off site. Table B.3 presents selected data for 18 tests with a yield of 20 kt or over, all detected off site. (Tests indicated by an asterisk (*) in Tables B.2 and B.3 are discussed in the main text as prime contributors to off-site population exposure.)

The nuclear test site was usually prepared for the conduct of a series of tests. Each series was given an "Operation" name. During the 1951 and 1952 Operations, the names of individual tests were repeated. The Operation name has been added in parentheses behind the test name for tests conducted in 1951 and 1952 as an aid to identifying tests. "T/S" stands for Tumbler/Snapper.

In an "open air" detonation, the expanded fireball did not usually contact the earth's surface. In a "surface" detonation, the exploded device or fireball usually was in contact with the surface of the earth. Open air and surface detonations are usually combined into the "atmospheric" category. "Underground" detonations were usually conducted deep enough beneath the earth's surface to contain all radioactive material.

In Tables B.1 through B.4, "type" refers to the method of deployment of the nuclear device at time of detonation. The meaning of the terms used in the tables is as follows:

"Type"		Means a nuclear device was:
<u>Open Air</u>		
Airburst	-	Fired from a cannon.
Airdrop	-	Dropped from an aircraft.
Balloon	-	Suspended from a tethered balloon.
Rocket	-	Launched by rocket.
<u>Surface</u>		
Crater	-	Placed shallow enough underground to produce a throw-out of earth when exploded.
Surface	-	Placed on or close to the earth's surface.
Tower	-	Mounted at the top of a steel or wooden tower.
<u>Underground</u>		
Shaft	-	Exploded at the bottom of a drilled or mined vertical hole.
Tunnel	-	Exploded at the end of a long horizontal drift mined into a mountain or mesa in a way that places the burst point deep within the earth.

[6] Abstracted from References [3] and [5].

TABLE B.1. NUCLEAR TESTS AT THE NTS OF LESS THAN 1.0 kt YIELD, 1951-1958

Test Name	Date	Type	Height (Feet)	Yield (kt)	Radioactive Release
ABLE (BUSTER)	10/22/51	Tower	100	0.1	On site only
RUTH	3/31/53	Tower	300	0.2	Off site
RAY	4/11/53	Tower	100	0.2	Off site
PROJ 56-1	11/01/55	Surface	0	0.0	Off site
PROJ 56-2	11/03/55	Surface	0	0.0	Off site
PROJ 56-3	11/05/55	Surface	0	0.0	Off site
PROJ 56-4	1/18/56	Surface	0	Slight	Off site
PROJ 57-1	4/24/57	Surface	0	0.0	Off site
FRANKLIN	6/02/57	Tower	300	0.14	Off site
LASSEN	6/05/57	Balloon	500	0.0005	On site only
COULOMB-A	7/01/57	Surface	0	0.0	None detected
PASCAL-A	7/26/57	Shaft	-500#	Slight	Off site
SATURN	8/10/57	Tunnel	-300	0.0	None detected
PASCAL-B	8/27/57	Shaft	-500	0.0	None detected
WHEELER	9/06/57	Balloon	500	0.197	Off site
COULOMB-B	9/06/57	Surface	0	0.3	Off site
PASCAL-C	12/06/57	Shaft	-250	Slight	On site only
COULOMB-C	12/09/57	Surface	0	0.5	Off site
VENUS	2/22/58	Tunnel	-100	0.001	None detected
URANUS	3/14/58	Tunnel	-114	0.001	None detected
OTERO	9/12/58	Shaft	-480	0.038	Off site
BERNALILLO	9/17/58	Shaft	-456	0.015	On site only
EDDY	9/19/58	Balloon	500	0.083	Off site
LUNA	9/21/58	Shaft	-485	0.0015	On site only
MERCURY	9/23/58	Tunnel	-213	Slight	None detected
VALENCIA	9/26/58	Shaft	-485	0.002	On site only
MARS	9/28/58	Tunnel	-142	0.013	On site only
HIDALGO	10/05/58	Balloon	340	0.077	Off site
COLFAX	10/05/58	Shaft	-350	0.0055	On site only
TAMALPAIS	10/08/58	Tunnel	-325	0.072	On site only
QUAY	10/10/58	Tower	100	0.079	Off site
NEPTUNE	10/14/58	Tunnel	-100	0.115	On site only
HAMILTON	10/15/58	Tower	50	0.0017	Off site
DONA ANA	10/16/58	Balloon	450	0.037	Off site
VESTA	10/17/58	Surface	0	0.024	Off site
RIO ARRIBA	10/18/58	Tower	72.5	0.090	Off site
SAN JUAN	10/20/58	Shaft	-230	0.0	None detected
WRANGELL	10/22/58	Balloon	1500	0.115	Off site
OBERON	10/22/58	Tower	25	0.0	None detected
RUSHMORE	10/22/58	Balloon	500	0.188	Off site
CATRON	10/24/58	Tower	72.5	0.021	Off site
JUNO	10/24/58	Surface	0	0.0017	On site only
CERES	10/26/58	Tower	25	0.0007	On site only
CHAVEZ	10/27/58	Tower	52.5	0.0006	Off site
EVANS	10/29/58	Tunnel	-850	0.055	On site only
MAZAMA	10/29/58	Tower	50	0.0	None detected
HUMBOLDT	10/29/58	Tower	25	0.0078	Off site
GANYMEDE	10/30/58	Surface	0	0.0	None detected
TITANIA	10/30/58	Tower	25	0.0002	Off site

Minus sign (-) means the number shown is feet below ground surface.

TABLE B.2. NUCLEAR TESTS AT THE NTS WITH YIELD OF 1 THROUGH 19 kt, 1951-1958

Test Name	Date	Type	Height (Feet)	Yield (kt)	Radioactive Release
ABLE (RANGER)	1/27/51	Airdrop	1060	1	Off site
BAKER (RANGER)	1/28/51	Airdrop	1080	8	Off site
EASY (RANGER)	2/01/51	Airdrop	1080	1	Off site
BAKER-2(RANGER)	2/02/51	Airdrop	1100	8	Off site
BAKER (BUSTER)	10/28/51	Airdrop	1120	3.5	Off site
CHARLIE(BUSTER)	10/30/51	Airdrop	1130	14	Off site
SUGAR (JANGLE)	11/19/51	Surface	4	1.2	Off site
UNCLE (JANGLE)	11/29/51	Crater	-17#	1.2	Off site
ABLE (T/S)	4/01/52	Airdrop	790	1	Off site
BAKER (T/S)	4/15/52	Airdrop	1110	1	Off site
DOG (T/S)	5/01/52	Airdrop	1040	19	Off site
*EASY (T/S)	5/07/52	Tower	300	12	Off site
*FOX (T/S)	5/25/52	Tower	300	11	Off site
GEORGE (T/S)	6/01/52	Tower	300	15	Off site
HOW (T/S)	6/05/52	Tower	300	14	Off site
*ANNIE	3/17/53	Tower	300	16	Off site
DIXIE	4/06/53	Airdrop	6020	11	Off site
GRABLE	5/25/53	Airburst	525	15	Off site
WASP	2/18/55	Airdrop	760	1	Off site
MOTH	2/22/55	Tower	300	2	Off site
*TESLA	3/01/55	Tower	300	7	Off site
HORNET	3/12/55	Tower	300	4	Off site
*BEE	3/22/55	Tower	500	8	Off site
ESS	3/23/55	Crater	-67	1	Off site
*APPLE-1	3/29/55	Tower	500	14	Off site
WASP PRIME	3/29/55	Airdrop	740	3	Off site
HA	4/06/55	Airdrop	36620	3	Off site
POST	4/09/55	Tower	300	2	Off site
*BOLTZMANN	5/28/57	Tower	500	12	Off site
WILSON	6/18/57	Balloon	500	10	Off site
*DIABLO	7/15/57	Tower	500	17	Off site
JOHN	7/19/57	Rocket	19110	2	Off site
*KEPLER	7/24/57	Tower	500	10	Off site
OWENS	7/25/57	Balloon	500	9.7	Off site
STOKES	8/07/57	Balloon	1500	19	Off site
*SHASTA	8/18/57	Tower	500	17	Off site
DOPPLER	8/23/57	Balloon	1500	11	Off site
FRANKLIN PRIME	8/30/57	Balloon	750	4.7	Off site
GALILEO	9/02/57	Tower	500	11	Off site
LAPLACE	9/08/57	Balloon	750	1	Off site
*FIZEAU	9/14/57	Tower	500	11	Off site
NEWTON	9/16/57	Balloon	1500	12	Off site
RANIER	9/19/57	Tunnel	-800#	1.7	None detected
*WHITNEY	9/23/57	Tower	500	19	Off site
CHARLESTON	9/28/57	Balloon	1500	12	Off site
MORGAN	10/07/57	Balloon	500	8	Off site
MORA	9/29/58	Balloon	1500	2	Off site
LEA	10/13/58	Balloon	1500	1.4	Off site
LOGAN	10/16/58	Tunnel	-820	5	None detected
SOCORRO	10/22/58	Balloon	1450	6	Off site
SANFORD	10/26/58	Balloon	1500	4.9	Off site
DE BACA	10/26/58	Balloon	1500	2.2	Off site
SANTA FE	10/30/58	Balloon	1500	1.3	Off site

Minus sign (-) means the number shown is feet below ground surface.

TABLE B.3. NUCLEAR TESTS AT THE NTS OF 20 kt YIELD AND OVER, 1951-1958

Test Name	Date	Type	Height (Feet)	Yield (kt)	Radioactive Release
FOX (RANGER)	2/06/51	Airdrop	1435	22	Off site
DOG (BUSTER)	11/01/51	Airdrop	1415	21	Off site
EASY (BUSTER)	11/05/51	Airdrop	1315	31	Off site
CHARLIE (T/S)	4/22/52	Airdrop	3445	31	Off site
*NANCY	3/24/53	Tower	300	24	Off site
*BADGER	4/18/53	Tower	300	23	Off site
*SIMON	4/25/53	Tower	300	43	Off site
ENCORE	5/08/53	Airdrop	2425	27	Off site
*HARRY	5/19/53	Tower	300	32	Off site
CLIMAX	6/04/53	Airdrop	1335	61	Off site
*TURK	3/07/55	Tower	500	43	Off site
*MET	4/15/55	Tower	400	22	Off site
*APPLE-2	5/05/55	Tower	500	29	Off site
*ZUCCHINI	5/15/55	Tower	500	28	Off site
*PRISCILLA	6/24/57	Balloon	700	37	Off site
HOOD	7/05/57	Balloon	1500	74	Off site
*SMOKY	8/31/57	Tower	700	44	Off site
BLANCA	10/30/58	Tunnel	-820#	22	Slight venting

Minus sign (-) means the number shown is feet below ground surface.

Tables B.4.a and B.4.b present selected data for nuclear tests at the NTS which released radioactivity detected off site from 1961 through 1990. (The "zero-yield" tests were safety experiments. In some of these tests, plutonium fuel was dispersed by detonation of the chemical explosive used as a trigger. The dispersed plutonium can be detected in small amounts in localized areas immediately outside the boundary of the Test Range Complex.)

Table B.4.a presents data for tests not designed to be contained. Table B.4.b presents similar data for tests designed to be contained but in which sufficient radiation escaped or was released to the environment that it was detected off site. Releases listed in Table B.4.b totalled about 28,000,000 Curies. Tests DES MOINES and BANEBERRY accounted for over half of this total.

Releases listed in these tables represent measured and estimated releases from the source location; they DO NOT represent the amount of radioactivity which escaped beyond the borders of the Test Range Complex.

TABLE B.4.a. NUCLEAR TESTS RELEASING RADIOACTIVITY DETECTED OFF THE TEST RANGE COMPLEX, 1961-1992: TESTS NOT DESIGNED TO BE CONTAINED

Test Name	Date	Type	Height (Feet)	Yield (kt)	Radioactive Release (Ci)
DANNY BOY	3/05/62	Crater	-110	0.43	850,000.
SEDAN	7/06/62	Crater	-635	104	15,000,000.
JOHNIE BOY	7/11/62	Crater	-2	0.5	Atmospheric; no est.
SMALL BOY	7/14/62	Tower	10	Low	Atmospheric; no est.
LITTLE FELLER-I	7/17/62	Surface	0	Low	Atmospheric; no est.
DOUBLE TRACKS	5/15/63	Surface	0	Zero	Pu disp.; no fission
CLEAN SLATE-1	5/25/63	Surface	0	Zero	Pu disp.; no fission
CLEAN SLATE-3	6/09/63	Surface	0	Zero	Pu disp.; no fission
SULKY	12/18/64	Shaft	-90	0.092	130,000.
PALANQUIN	4/14/65	Crater	-280	4.3	11,000,000.
CABRIOLET	1/26/68	Crater	-171	2.3	220,000.
BUGGY	3/12/68	Crater	-135	5.4	1,200,000.
SCHOONER	12/08/68	Crater	-355	30	3,700,000.

Minus sign (-) means the number shown is feet below ground surface.

TABLE B.4.b. NUCLEAR TESTS RELEASING RADIOACTIVITY DETECTED OFF THE TEST RANGE COMPLEX, 1961-1992: TESTS DESIGNED TO BE CONTAINED

Test Name	Date	Type	Height (Feet)	Yield (kt)	Radioactive Release (Ci @ R+12 hr)	Release Remark Code
ACCIDENTAL RELEASES						
ANTLER	9/15/61	Tunnel	-1318[1]	2.6	210,000.	OS
FEATHER	12/22/61	Tunnel	-812	Low[2]	380.	MOS
PAMPAS	3/01/62	Shaft	-1191	Low	2,000.	MOS
PLATTE	4/14/62	Tunnel	-628	1.85	1,900,000.	OS
EEL	5/19/62	Shaft	-714	Low	1,900,000.	OS
DES MOINES	6/13/62	Tunnel	-660	Low	11,000,000.	OS
BANDICOOT	10/19/62	Shaft	-800	Low	3,000,000.	OS
EAGLE	12/12/63	Shaft	-540	Low	960.	MOS
PIKE	3/13/64	Shaft	-376	LT.20	120,000.	OS
ALVA	8/19/64	Shaft	-545	LT.20	6,400.	DBAO
DRILL	12/05/64	Shaft	-615	3.4	61,420.	OS
PARROT	12/16/64	Shaft	-592	1.3	230,000.	OS
ALPACA	2/12/65	Shaft	-737	LT.20	40,000.	MOS
TEE	5/07/65	Shaft	-624	LT.20	1,620.	MOS
DILUTED WATERS	6/16/65	Shaft	-640	LT.20	30,000.	MOS
RED HOT	3/05/66	Tunnel	-1330	LT.20	1,000,000.	OS
FENTON	4/23/66	Shaft	-549	LT.20	17,000.	DBAO
PIN STRIPE	4/25/66	Shaft	-970	LT.20	210,000.	OS
DOUBLE PLAY	6/15/66	Tunnel	-1075	LT.20	826,000.	MOS
DERRINGER	9/12/66	Shaft	-835	LT.20	12,000.	MOS
NASH	1/19/67	Shaft	-1194	GT.20[3]	69,000.	MOS
UMBER	6/29/67	Shaft	-1018	LT.20	26,000.	MOS
DOOR MIST	8/31/67	Tunnel	-1463	LT.20	400,000.	MOS
HUPMOBILE	1/18/68	Shaft	-810	10	120,000.	MOS
POD	10/29/69	Shaft	-1025	GT.20	3,931.	MOS
SCUTTLE	11/13/69	Shaft	-540	LT.20	210.	DBAO
SNUBBER	4/21/70	Shaft	-1125	LT.20	55,000.	MOS
BANEBERRY	12/18/70	Shaft	-910	10	6,700,000.	MOS
DIAGONAL LINE	11/24/71	Shaft	-867	LT.20	6,800.	DBAO
RIOLA	9/25/80	Shaft	-1360	LT.20	3,100.	MOS
OTHER RELEASES[4]						
YUBA	6/05/63	Tunnel	-800	Low	36,110.	O-MOS
OCONTO	1/23/64	Shaft	-868	LT.20	30,000.	O-DBAO
MIDI MIST	6/26/67	Tunnel	-1230	LT.20	1,318.	C-DBAO
MINT LEAF	5/05/70	Tunnel	-1330	LT.20	390,000.	C-MOS
MISTY RAIN	4/06/85	Tunnel	-1276	LT.20	45.	C-MOS
GLENCOE	3/22/86	Shaft	-2000	20-150	0.074	O-MOS
MIGHTY OAK	4/10/86	Tunnel	-1294	LT.20	33,516.	C-MOS

1 Minus sign (-) means the number shown is feet below ground surface.
2 Prior to 1964, Low meant less than 20 kt.
3 GT.20 means 20 to 200 kt as used here.
4 All remaining releases, detected off site, which are not listed above in accidental releases or in Table B.4.a.

Release Remark Codes: O = operational, C = controlled; OS = off site unqualified, MOS = minor off site, DBAO = detected by aircraft only.

Table B.5 presents basic information on 12 nuclear tests conducted at continental U.S. locations away from the NTS. (The TRINITY test was conducted in New Mexico more than five years before the NTS was established.) These off-site detonations were conducted for various reasons as stated in the remarks column of the table. The test-detection experiments and seismic calibrations were important to the United States in developing means of detecting and identifying underground tests by foreign countries and in estimating the yield of such tests. The gas stimulation experiments used nuclear explosives to stimulate natural gas production in low productivity gas-bearing formations. These detonations represent the last efforts of the AEC to develop peaceful uses for atomic explosives under the now inactive Plowshare Program.

TABLE B.5. NUCLEAR DETONATIONS AT CONTINENTAL UNITED STATES LOCATIONS AWAY FROM THE NEVADA TEST RANGE COMPLEX, 1945-1973

Test Name	Location	Date	Yield (kt)	Remarks
TRINITY	Alamogordo, NM	7/16/45	19	First nuclear test
GNOME	Carlsbad, NM	12/10/61	3	In salt dome
SHOAL	Fallon, NV	10/26/63	12	Test detection experiment
SALMON	Hattiesburg, MS	10/22/64	5.3	Test detection experiment
LONG SHOT	Amchitka, Alaska	10/29/65	80	Test detection experiment
STERLING	Hattiesburg, MS	12/03/66	0.4	Test detection experiment
GASBUGGY	Farmington, NM	12/10/67	29	Gas stimulation
FAULTLESS	Central NV	1/19/68	200+	Seismic calibration
RULISON	Grand Valley, CO	9/10/69	40	Gas stimulation
MILROW	Amchitka, Alaska	10/02/69	1000	Seismic calibration
CANNIKIN	Amchitka, Alaska	11/06/71	1000+	Test of warhead
RIO BLANCO	Rifle, CO	5/17/73	99[1]	Gas stimulation

[1] Three 33-kt devices at different depths in the same shaft.

NOTE: TRINITY was placed on a steel tower. GNOME was placed in a mined cavity. Each of the others was placed in a drilled shaft.